

What is claimed is:

1. An apparatus for processing data comprising:

a plurality of individual processing elements arranged in a serial array wherein a
5 first processing element precedes a second processing element which precedes an n th
processing element; and,

a clock distribution circuit in electrical communication with each processing
element of the plurality of individual processing elements in the serial array such that, in
use, a clock signal propagated along the clock distribution circuit arrives at each
10 processing element delayed relative to the clock signal arriving at a preceding processing
element;

wherein a time equal to an exact number of clock cycles, k , where k is
greater than zero, from when the data is clocked into a processing element to when the
data is clocked in by a subsequent processing element is insufficient for providing
15 accurate output data from the processing element but wherein the same time with the
additional delay is sufficient and wherein new data to be processed is clocked in by the
same processing element after the exact number of clock cycles, k .

2. The apparatus according to claim 1, the serial array having a first path in a first
20 direction and a second path in a second other direction, the second path at each stage
having a process time shorter than the process time of the first path at each stage.

3. The apparatus according to claim 2 wherein the clock signal is distributed
independently to each processing element.

4. The apparatus according to claim 3 wherein the delay between any two adjacent
processing elements is approximately a same delay.

5. The apparatus according to claim 4 wherein the direction of propagation of the
30 clock signal is switchable.

6. The apparatus according to claim 4 wherein the exact number of clock cycles, k , is one clock cycle.

5 7. The apparatus according to claim 2 wherein the clock signal is gated from a preceding processing element to a next processing element.

8. The apparatus according to claim 7 wherein the direction of propagation of the clock signal is switchable.

10 9. The apparatus according to claim 2 wherein at least a processing element of the serial array is time-synchronized to an external circuit.

10. The apparatus according to claim 9 wherein the external circuit includes a memory buffer.

11. The apparatus according to claim 10 wherein the external circuit includes an input/output port for receiving data from an external data source and for providing said data to the memory buffer.

20 12. The apparatus according to claim 11 wherein the serial array comprises:
a first pipeline array having a first predetermined number of processing elements, n ; and,
a second different pipeline array having a second predetermined number of processing elements, m .

25 13. The apparatus according to claim 12 wherein at least a processing element of the first pipeline array is in electrical communication with the memory buffer via a hardware connection, the at least a processing element of the first pipeline array being time-synchronized to the memory buffer for retrieving data therefrom.

30 14. The apparatus according to claim 13 wherein the at least a processing element of the first pipeline array is a first processing element of the first pipeline array.

15. The apparatus according to claim 13 wherein the n th element of the first pipeline array and the m th element of the second pipeline array are in electrical communication via a hardware connection, such that data having been provided to the first processing
5 element of the first pipeline array and propagated to the n th processing element thereof is further propagated to the m th processing element of the second pipeline array for additional processing therein.

16. The apparatus according to claim 15 wherein the first predetermined number of
10 processing elements, n , and the second predetermined number of processing elements, m are a same predetermined number of processing elements and wherein, in use, the delay to the n th element and to the m th element is approximately equal such that a tail-to-head data transfer between the n th element of the first pipeline array and the m th element of the second pipeline array is substantially time-synchronized.

17. The apparatus according to claim 13 wherein at least a processing element of the
15 second pipeline array is in electrical communication with the memory buffer via a second hardware connection, the at least a processing element of the second pipeline array being time-synchronized to the memory buffer for retrieving data therefrom.

18. The apparatus according to claim 17 wherein the at least a processing element of
20 the second pipeline array is a first processing element of the second pipeline array.

19. The apparatus according to claim 17 wherein the n th element of the first pipeline
25 array and the m th element of the second pipeline array are in electrical communication via a hardware connection, such that data having been provided to the first processing element of the first pipeline array and propagated to the n th processing element thereof is further propagated to the m th processing element of the second pipeline array for additional processing therein.

20. The apparatus according to claim 17 comprising a third pipeline array having a third predetermined number of processing elements, q .

21. The apparatus according to claim 20 wherein at least a processing element of the third pipeline array is in electrical communication with the memory buffer via a third hardware connection, the at least a processing element of the second pipeline array being time-synchronized to the memory buffer for retrieving data therefrom.

22. The apparatus according to claim 21 wherein the at least a processing element of the third pipeline array is a first processing element of the third pipeline array.

23. The apparatus according to claim 21 wherein the n th element of the first pipeline array and the m th element of the second pipeline array are in electrical communication via a first hardware connection, and the first element of the second pipeline array and the first element of the third array are in electrical communication via a second hardware connection, such that that a tail-to-head data transfer between the n th element of the first pipeline array and the m th element of the second pipeline array is substantially time-synchronized and such that a head-to-tail data transfer between the first element of the second pipeline array and the first element of the third pipeline array is substantially time-synchronized.

24. The apparatus according to claim 12 comprising a third pipeline array having a third predetermined number of processing elements, q .

25. The apparatus according to claim 24 wherein the n th element of the first pipeline array and the m th element of the second pipeline array are in electrical communication via a first hardware connection, and the first element of the second pipeline array and the first element of the third array are in electrical communication via a second hardware connection.

26. A switchable processing element comprising:

a first port for receiving a first clock signal;
a second port for receiving a second other clock signal;
a switch operable between two modes for selecting one of the first clock signal
and the second other clock signal; and

5 wherein the selected one of the first clock signal and the second other clock signal
is provided to the processing element.

27. A method for processing data comprising the steps of:

- 10 (a) providing a pipeline processor including a plurality of individual
processing elements arranged in a serial array such that a first processing element
precedes a second processing element which precedes an nth processing element;
- 15 (b) providing a clock signal to each processing element of the plurality of
individual processing elements in the serial array such that the clock signal arrives at each
individual processing element beyond the first processing element delayed relative to the
clock signal arriving at a preceding processing element;
- 15 (c) providing data to the first processing element for processing therein; and,
15 (d) propagating the data to at least a next processing element for additional
processing therein,

20 wherein the clock signal provided to an element in the plurality of
individual processing elements is delayed relative to the clock signal provided to another
element of the plurality of individual processing elements by a substantial amount
relative to the clock period.

28. A method according to claim 27 wherein a time equal to an exact number of clock
25 cycles, n , where $n > 0$ from when the data is provided to the first processing element to
when the data is propagated to the at least a next processing element is insufficient for
providing accurate output data from the first processing element but wherein the same
time with the additional delay is sufficient and wherein new data to be processed is
provided to the first processing element after the exact number of clock cycles, n .

30

29. The method according to claim 27 wherein the at least a next processing element propagates data in a second other processing direction away from the first processing element for additional processing therein.

5 30. The method according to claim 29 wherein the step of providing data comprises the steps of:

synchronizing the first processing element to an external circuit, the external circuit for receiving the data for processing by the first processing element from an external source; and,

10 reading the data for processing by the first processing element from the external circuit.

31. The method according to claim 30 wherein the external circuit is a memory buffer for receiving the data for processing by the first processing element.

32. The method according to claim 29 wherein one of the first and second direction requires a shorter processing time relative to the other.

33. The method according to claim 32 wherein the clock signal is distributed independently to each processing element.

34. The method according to claim 33 wherein the exact number of clock cycles, k , is one clock cycle.

25 35. The method according to claim 33 wherein the delay between any two adjacent elements is approximately a same delay.

36. The method according to claim 33 wherein the delay plus the exact number of clock cycles is a longer period of time than the processing time in the direction of delay.

30

37. The method according to claim 36 wherein the exact number of clock cycles minus the delay is a longer period of time than the processing time in the direction other than the direction of delay but a shorter period of time than the processing time in the direction of the delay.

5

38. The method according to claim 37 wherein the clock cycle is at least an average of the processing times in each direction.

10

39. The method according to claim 32 wherein the clock signal is gated from a preceding processing element to a next processing element, each processing element having therein circuitry for causing a known delay in the clock signal.

40. The method according to claim 32 wherein the data is provided for encryption to the pipeline processor.

15

41. A method for processing data within a pipeline processor comprising the steps of:

(a) providing a clock signal in a first direction along a first portion of the pipeline processor having a number, n , processing elements such that the clock signal arrives at each individual processing element beyond the first processing element of the first portion delayed relative to the clock signal arriving at a preceding processing element of the same first portion;

20

(b) providing a clock signal in a second substantially opposite direction along a second other portion of the pipeline processor having a same number, n , processing elements such that the clock signal arrives at each individual processing element beyond the first processing element of the second other portion delayed relative to the clock signal arriving at a preceding processing element of the same second other portion;

25

(c) providing data to the first processing element of the first portion of the pipeline processor for processing therein;

wherein the delay to the last processing element of the first portion is an approximately same delay as the delay to the last processing element of the second

30

portion, such that at center of the pipeline processor the two adjacent processing elements are in synchronization.

42. The method according to claim 41 wherein the data is provided for encryption by the pipeline processor.

43. A macro for use in layout of an apparatus for processing data comprising:
a plurality of individual processing elements arranged serially and having a clock input conductor and a clock output conductor, the clock input conductor in communication with a clock conductor having increased length from the clock input conductor to each subsequent element within the within the plurality of individual processing elements and wherein the clock conductor has decreased length from the clock output conductor to each subsequent element within the within the plurality of individual processing elements,

wherein the clock input conductor and output conductor are arranged such that adjacently placed macros form space efficient blocks within a layout and such that the input clock conductor of one macro and the out clock conductor of an adjacent macro when coupled have approximately a same conductor path length as the conductor path length between adjacent elements within a same macro when the macros are disposed in a predetermined space efficient placement.